

**METHOD AND APPARATUS FOR
SIGNALLING IN A SHARED
PROTECTION RING ARCHITECTURE**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT OF FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

5 BACKGROUND OF THE INVENTION

1. TECHNICAL FIELD

[0003] This invention relates in general to telecommunications and, more particularly, to shared protection architectures.

2. DESCRIPTION OF THE RELATED ART

10 [0004] Over the last decade, the importance of telecommunications has increased dramatically. In order to accommodate the vast amount of information passed over telecommunications systems, such as the Public Switched Telephone Network (PSTN) and data networks, copper wires are being replaced with optical fibers, which are capable of carrying significantly more information.

15 [0005] A single fiber may transmit information over many different channels using DWDM (dense wavelength division multiplexing) techniques.

Improvements in fiber technology and electronics are increasing the number of channels that may be distinguished over a fiber and, thus, the amount of information that may be passed by a single fiber.

[0006] Increases in information bandwidth over a fiber, however, increase the importance of providing mechanisms to bypass failures in the network, until the failure can be corrected. Common failures include, for example, fiber breakages (typically caused by construction activities inadvertently cutting a fiber), fiber disconnects caused by accidents in the central office, and network element failures, such as laser failures.

[0007] In order to maintain communications in spite of a failure, ring architectures are often used. In a ring architecture, a series of network elements are connected in a ring, such as shown in Figure 1. Each ring has multiple network elements coupled to one another to form a closed loop. Typically, there are four fibers connecting adjacent network elements – two working fibers and two protection fibers, although other configurations are possible. The working fibers (W) carry traffic between adjacent nodes. Protection fibers (P) are available to carry traffic in the event of a working fiber failure. The protection fibers also convey control information between network elements; when not being used for traffic, the protection fibers may carry low-priority interruptible traffic. As shown in Figure 1, network elements may be shared between different rings.

[0008] The ring architecture shown in Figure 1a is a very simple architecture. In many circumstances, multiple rings may connect various network elements as shown in Figure 1b. Failures of a working fiber in any of the rings may cause protect lines in multiple rings to be used.

[0009] Figure 2a illustrates one prior art method of circumventing a failure of a working fiber W. In this embodiment, a ring having five network elements

12 (referenced individually as network elements 12a-12e) has a broken working fiber W between network elements 12c and 12d. For purposes of illustration, only one working fiber W and one protection fiber P is shown, it being understood that a similar pair of working and protection fibers are used for traffic in the opposite direction. To pass traffic between network elements 12c and 12d, network element 12d connects the working lines 16de to protect lines 18cd and network element 12c connects working lines 16bc to protect lines 18cd. In other words, traffic that would normally be routed over working lines 16cd is switched to the associated protect lines 18cd. This is referred to as a "span" switch.

[0010] Figure 2b illustrates a situation where both the working and protection lines have failed between network elements 12c and 12d. In this case, a "ring" switch is implemented where working line 16de is rerouted to protect line 18de and working line 16bc is rerouted to protect line 18bc. Accordingly, the remaining viable protect lines all carry traffic. Every network element can still communicate with all the other network elements 12 on the ring.

[0011] Figure 3 illustrates an architecture wherein two rings 10a and 10b share a protection path between network elements 12a and 12b. In WO 99/23773 (PCT/IB98/01955) to Elahmadi et al, the use of a single physical span between these two network elements is proposed. This single span provides protection for two rings 10a and 10b. A failure on either ring can be remedied by using the shared protect line 18ab to carry traffic. This architecture reduces costs, which can be significant if the distance between the shared network elements is long (or there are other infrastructure costs involved), but increases the chance of a traffic outage on one ring if a failure occurs while there is another failure on another ring.

[0012] Another problem with shared protection spans is the lack of an established protocol. To realize the full cost savings inherent in one or more shared protection spans, it is desirable that traditional, fully redundant network elements be used in portions of the rings. Preferably, the operation of the shared protection network elements can be transparent to the traditional network elements, eliminating costs involved in replacing or modifying the traditional network elements. Further, it is important to maximize the use of shared spans to correct failures, so that communications traffic is maintained as much as possible.

- 10 [0013] Therefore, a need has arisen for a method and apparatus for using shared protect lines along with traditional protection architectures as efficiently as possible.

BRIEF SUMMARY OF THE INVENTION

[0014] In the present invention, a method and apparatus for controlling communications in a shared protection architecture is provided, where first and second network elements support communications over a plurality of working channels of respective rings using a shared protection channel common to all of the rings. Responsive to an indicated span switch on a first ring, control information for the first ring is passed over the shared protection channel while the network elements indicate the availability of the shared protection channel to rings other than the first ring. Responsive to an indication that the shared protection channel is needed to pass communications traffic for a second ring, the network element cease to pass the control information for the first ring over the shared protection channel and indicate the non-availability of the shared protection channel to rings other than the second ring.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0015] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

5 [0016] Figures 1a and 1b illustrate prior art ring architectures;

[0017] Figure 2a and 2b illustrate prior art span switches and ring switches, respectively;

[0018] Figure 3 illustrates a prior art shared protection scheme;

10 [0019] Figure 4 illustrates a shared protection span with no communications errors on any associated ring;

[0020] Figure 5 illustrates a shared protection span with a working channel failure between shared protection network elements;

[0021] Figure 6a illustrates a shared protection span with an indicated span switch on one ring;

15 [0022] Figure 6b illustrates a shared protection span with an indicated span switch on two rings;

[0023] Figure 7 illustrates a shared protection span with an indicated ring switch on one ring;

20 [0024] Figure 8 illustrates a shared protection span with an indicated span switch on one ring followed by an indicated ring switch on another ring;

[0025] Figure 9 illustrates an exemplary three ring architecture with no communications errors;

[0026] Figure 10 illustrates the architecture of Figure 9 with an indicated ring switch on one ring;

[0027] Figure 11 illustrates the architecture of Figure 9 with an indicated ring switch on a different ring;

5 [0028] Figure 12 illustrates the architecture of Figure 9 with an indicated span switch on one ring;

[0029] Figure 13 illustrates the architecture of Figure 9 with an indicated span switch on one ring followed by a ring switch on another ring;

10 [0030] Figure 14 illustrates the architecture of Figure 9 with two ring switches formed pursuant to a failure of working and shared protection spans;

[0031] Figure 15 illustrates the architecture of Figure 9 with an indicated span switch on one ring followed by an indicated span switch on another ring;

[0032] Figures 16a through 16b illustrate the architecture of Figure 9 with two spans switches followed by a ring switch; and

15 [0033] Figure 17 illustrates a state diagram showing operation of the shared protection network elements.

DETAILED DESCRIPTION OF THE INVENTION

[0034] The present invention is best understood in relation to Figures 4 - 17 of the drawings, like numerals being used for like elements of the various drawings.

5 [0035] Figures 4 - 8 illustrate a pair of network elements 12a and 12b using a shared protection channel 22ab communicating as different switches are implemented to maintain communication in various rings. In the illustrated embodiment, three rings, Ring1, Ring2 and Ring3, are coupled to the each network element 12a and 12b. For purposes of illustration, only one channel pair, a working channel pair 20 and a protection channel pair 22, are shown from each ring; these channel pairs are supported by a single shared protection channel pair 22ab. In normal operation, as shown in Figure 4, working channels 20ab1 are coupled to working channels 20 of Ring1, working channels 20ab2 are coupled to working channels 20 of Ring2 and working channels 20ab3 are coupled to working channels 20 of Ring3. Working channels 20 would typically be from separate fibers coupled to the network elements, although they could be channels from separate rings carried on a single fiber. In an actual implementation, each network element would be coupled to multiple fibers, each fiber providing communication over many channels. Similarly, the protection line between network elements 12a and 12b would support multiple channels as well. The illustrated embodiments of Figures 4 - 8 are used to show the operations that occur between sets of channels of the various fibers and rings coupled to the network elements that are protected using a shared protection channel.

25 [0036] During normal operation the shared protection channels may be used to transfer control information between network elements 12a and 12b. A NR (no requests) signal is output from both network elements 12a and 12b on their outgoing protection channels 22 during normal operation.

[0037] Figure 5 illustrates the operation of the network elements 12a and 12b where a working channel between the network elements fails. In Figure 5, working channel 20ab3 fails. This causes a span switch to occur at both network elements 12a and 12b, and the shared protection channel pair 22ab is used to pass traffic from the working channels 20 of Ring3. The network elements 12a and 12b output a SPAN-SW (span switch signal) on their respective outgoing, non-shared protection channels 22 for Ring3 and output a LOP (lockout of protection) signal on the outgoing protection channels for Ring1 and Ring2. The LOP signal indicates that the shared protection channel pair 22ab between network elements 12a and 12b is no longer available. The LOP signal includes a field indicating the source of the signal. The LOP is output as long as the span switch is in place.

[0038] Figure 6a illustrates the operation of the network elements 12a and 12b where a span switch occurs elsewhere on a ring coupled to network elements 12a and 12b. In Figure 6, a span switch has occurred on Ring3, thus causing a SPAN-SW signal to be received on the incoming protection channels 22 of Ring3 at the network elements 12a and 12b. In order to propagate the SPAN-SW signal, the shared protection channel pair 22ab is coupled between the protection channels 22 of Ring3. NR signals are output on outgoing, non-shared protection channels for Ring1 and Ring2, since the shared protection channel pair 22ab is still available, if necessary, to pass communications traffic, which would be considered a higher priority, as will be shown below.

[0039] In Figure 6b, a second span switch on Ring2 occurs in addition to the span switch on Ring3, as indicated by the SPAN-SW signal on the incoming protection channels 22 of Ring 2. Since the shared protection channel pair 22ab is being used to passthrough the signals from protection channels 22 of Ring3, it is not available for a second passthrough operation. Hence, a LOP is signal is output on outgoing, non-shared protection channels 22 for Ring2. A NR signal is still placed on the outgoing, non-shared protection channels 22 of Ring1, since

the shared protection channels 18ab are still available to correct a communications failure. If the failure necessitating the span switch is corrected, the LOP signal is dropped and Ring2 could use the shared protection channel pair for control information passthrough. Also, if the failure necessitating the span switch on Ring2 is corrected, the LOP is dropped as well.

[0040] In Figure 7, a ring switch is indicated on Ring3, as indicated by the RS (ring switch) signal received at the incoming protection channels 22 of Ring3. In this case, the protection channels 22 will be used to pass communications traffic once the ring switch is set up. The RS signals are passed over the shared protection channels to the outgoing protection channels 22, so that every network element 12 in the ring receives an indication that a ring switch is needed. An ACK (acknowledge) signal (not shown) is returned to complete the setup protocol. The protection channels 22 of Ring3 are then coupled to the shared protection channel pair 22ab to pass communications traffic. A LOP signal is placed on the outgoing, non-shared protection channels of Ring1 and Ring2, since the shared protection channels are no longer available. When the ring switch is dropped, the LOP signal is dropped as well.

[0041] In Figure 8, a span switch on Ring3 is superseded by a ring switch on Ring1. The initial condition for the span switch on Ring2 is shown in Figure 6a. When the RS signal is received at the incoming protection channels of Ring1, the shared protection channel pair 22ab is decoupled from passing control information from the protection channels 22 of Ring3 and is coupled to the protection channels 22 of Ring1, which will be passing communications traffic once the ring switch is set up at all of the associated network elements on the ring. To indicate that the shared protection channel pair 22ab is no longer available, a LOP signal is placed on the outgoing, non-shared protection channels 22 of Ring2 and Ring3. It should be noted that this does not affect the passing of

traffic over the span switch on Ring3, which remains operable, it only stops the passthrough of the control information through network elements 12a-b.

[0042] The passthrough of control information could also be superceded by a span switch between network elements 12a and 12b, as shown in Figure 5.

5 [0043] Figures 9 – 16b illustrate the operation of the network elements of Figures 4 – 8 in a multiple ring configuration. Figure 9 illustrates a network comprising eight network elements 12, individually referenced as network elements 12a – 12h. The spans between network elements 12a and 12b, between network elements 12b and 12c, and between network elements 12b and 12d use a
10 shared protection scheme, as shown in Figures 4 – 8. The spans between the remaining network elements use a conventional fully redundant protection scheme.

[0044] The network configuration 30 of Figure 9 provides three ring structures: RingA, RingB and RingC. Network elements 12a, 12b, 12d, 12g and
15 12h form RingA. Network elements 12b, 12d, 12f and 12c form RingB. Network elements 12a, 12b, 12c and 12e form RingC. As above, working channels 20 are shown in solid line and protection channels 22 are shown in dashed lines. Network elements 12a, 12b, 12c and 12d support shared protection lines as described above. The remaining network elements can be of conventional
20 design.

[0045] During normal operation (no working channel or protection channel failures), each of the shared protection network elements 12a-12d output NR signals as described in connection with Figure 4.

[0046] Figures 10 – 16b illustrate different failure scenarios. In Figure 10, a
25 ring switch is indicated away from the shared protection due to a failure of working and protection channels between network elements 12g and 12h.

Network elements 12g and 12h will issue RS signals to network elements 12d and 12a, respectively, to set up a ring switch. The RS signals will pass through the remaining network elements in the ring on the shared and non-shared channels (for example, the RS signal from network element 12h will be sent to network element 12a on non-shared protection channel, where it will be passed to network elements 12b and 12d through their shared protection channels, and finally to network element 12g via the non-shared protection channel). An ACK signal will pass in the opposite direction via the same shared and non-shared protection channels. The shared protection network elements that are part of the ring switch, i.e., network elements 12a and 12d, will issue LOP signals on their outgoing, non-shared protection channels, as described in connection with Figure 7. Network element 12b does not issue a LOP signal, since it is not connected to any outgoing, non-shared protection lines.

[0047] Figure 11 illustrates the effect of a loss of working and protection channels between network elements 12c and 12f. In this case, a ring switch is set up around RingB, with network elements 12c and 12f performing the coupling of the working and protection channels. Each network element in RingB that is coupled to a non-shared protection channel outside of the RingB issues an LOP signal. Hence, network element 12c issues a LOP signal to network element 12e and network element 12d issues a LOP signal to network element 12g.

[0048] In Figure 12, a span switch is implemented to circumvent a working channel failure between network elements 12a and 12e. Network element 12e couples the working channel from network element 12c with the protection channel from network element 12a; network element 12a couples the working channel from network element 12b with the protection channel from network element 12c. The shared protection channels 22ab and 22bc are placed in passthrough mode to pass control information around RingC.

[0049] Figure 13 illustrates a span switch in RingC followed by a ring switch in RingA caused by a loss of working and protection channels between network elements 12d and 12g. The initial condition caused by the span switch in RingA will be the same as shown in Figure 12. Specifically, the shared protection channels 22ab and 22bc will be used to pass control information for RingC. The ring switch in RingA, however, supercedes the control passthrough in RingC (the span switch continues to function without passing the control information). Consequently, shared protection channel 22ab stops passing control information for RingC and is used to setup the ring switch in RingA by passing RS and ACK signals. Subsequently, protection channel 22ab is used to pass traffic for the ring switch. An LOP signal is output to network element 12a to network element 12e and from network element 12d to network element 12f.

[0050] Figure 14 illustrates a span switch in RingC followed by a span switch in RingA, caused by a working channel failure between network elements 12g and 12h. The initial condition for the span switch in RingC is shown in Figure 12. The span switch in RingC causes a SPAN-SW signal to be sent from network element 12h to network element 12a and from network element 12g to network element 12d. Since the shared protection channel pair 22ab is used by the span switch in RingC, network element 12a returns a LOP signal to network element 12h, indicating that the shared protection channel 22ab is not available to pass control information; nonetheless, the span switch can be implemented to pass communications traffic over the protection channel between network elements 12g and 12h.

[0051] In Figure 15, ring switches in RingC and RingA are necessitated by a failure of the working and shared protection channels between network elements 12a and 12c. Shared protection channel 22bd is used for the ring switch for RingA; the remaining spans of the ring switches are made using non-shared channels. Network element 12c issues a LOP signal to network element 12f and

network element 12d issues a LOP to network element 12f. The remaining network elements are involved in the ring switch and do not receive LOP signals.

[0052] Figures 16a-b illustrate a situation which could involve an isolated network element, but for the prioritization of failure conditions. In Figure 16a, a working channel failure between network elements 12e and 12a causes a span switch. As shown in connection with Figure 12, network elements 12a, 12b and 12c provide a passthrough path for control information over shared protection channels 22ab and 22bc. A second span switch is necessitated by a working channel failure between network elements 12d and 12f. In response to receiving the SPAN-SW signal from network elements 12d and 12f, network element 12c issues an LOP signal to network element 12f. At this point, shared protection channel 22bc continues to be used for passing control information for RingC. RingB does not have a passthrough for control information, however, the span switch is still implemented such that communications traffic can pass between network elements 12f and 12d.

[0053] As shown in Figure 16b, an ensuing failure of working and protection channels between network elements 12g and 12h causes a ring switch on RingA. When network element 12 receives a RS signal, it drops the passthrough of control information for RingC and passes the RS to network element 12b via shared protection channel 22ab. Similarly, network element 12b drops the passthrough of control information through protection channel 22bc and couples shared protection channel 22ab to protection channel 22bd. After the RS and ACK signals have promulgated through each network element in RingA, the ring switch is implemented and shared protection channels 22ab and 22bc are used to pass traffic. LOP signals are generated by network element 12d to network element 12f and by network element 12a to network element 12e.

[0054] With reference to Figure 4, Figure 17 illustrates a state diagram showing the signals generated by shared protection network elements 12a and 12b according to various states of the shared protection channel 22ab. In state 40, the SP (shared protection channel) 22ab is not being used by any ring coupled to the network elements 12a-b, either for control information passthrough or for communications traffic. As shown in Figure 4, an NR signal is generated on all outgoing, non-shared protection (NSP) channels 22.

[0055] If the network elements 12a-b receive a SPAN-SW signal, indicating a span-switch on a RingR (where RingR is an arbitrary ring supported by the shared protection network elements), the state transitions to state 42, where the shared protection channel 22ab is used for control information passthrough (as shown in connection with Figure 6a). NR signal are output on the non-shared protection channels 22 for all rings other than RingR, except for rings that subsequently have a SPAN-SW indication. For rings with a subsequent SPAN-SW indication, an LOP signal is generated on the non-shared protection channels 22.

[0056] Once the failure is remedied, the state transitions to state 40. If there were subsequent SPAN-SW signals that were still enabled, the state would transition back to state 42.

[0057] If a ring switch is indicated on RingM (an arbitrary ring) or the RingM working channel 20ab between the network elements 12a-b fails, while in either state 40 or state 42, the state transitions to state 44, where the shared protection channel is used to carry traffic. In the case of a ring switch, the shared protection channel 22ab is coupled between other protection channels 22 to effect the ring switch (Figure 7 and Figure 8). In the case of a working channel failure, the shared protection channel 22ab is coupled between working channels 20 in a span switch (Figure 5). In either case, LOP signals are generated on the non-

shared protection channels of all rings other than RingM. In the case of the span switch, the SPAN-SW signal is generated on the non-shared protection channels associated with RingM.

[0058] Again, once the failure is remedied, the state returns to state 40.

- 5 [0059] If there is a failure of the shared protection channel 22ab, the shared protection channel will be unable to pass either traffic or control information (state 46). In this case, ring switches can be formed for any ring where the associated working channel 20ab has failed as well (Figure 15). Otherwise, a LOP signal is generated on the non-shared protection channels 22 for each ring.
- 10 When the failure is corrected, the state returns to state 40. The state could also transition to state 46 from either state 42 or state 44.

- [0060] The present invention provides significant advantages over the prior art. First, the LOP, NR, RS, and SPAN-SW signals are compatible with fully redundant network elements. The actions taken in response to these signals
- 15 allow integration of traditional network elements with the shared protection network elements. The prioritization of action based on various conditions described herein provides maximization of the shared protection channels for maintaining communications traffic, while allowing use of the shared protection channels for passing control information where appropriate. Situations where a
- 20 node could be isolated from status signals from other network elements due to multiple line failures, such as shown in Figures 16a-b, are eliminated; therefore, all network elements may participate restorations regardless of the sequence of failures.

- [0061] Although the Detailed Description of the invention has been directed
- 25 to certain exemplary embodiments, various modifications of these embodiments, as well as alternative embodiments, will be suggested to those skilled in the art.

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PATENT APPLICATION

The invention encompasses any modifications or alternative embodiments that fall within the scope of the Claims.

Patent 135740